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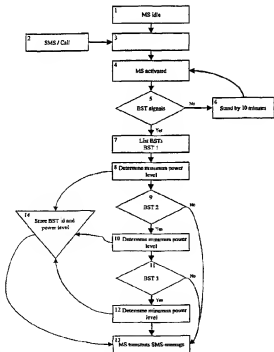
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(54) Title: A MOBILE STATION FOR USE AS A LOCATOR DEVICE WITHIN A CELLULAR COMMUNICATION SYSTEM



(57) **Abstract:** A mobile station for use as a locator device within a cellular communication system or network having a plurality of base stations. The mobile station comprises identification means for identifying and selecting one or more base stations having sufficient signal strength to communicate with the mobile station, and power level determining means to determine for one or more selected base stations corresponding minimum signal power levels for signals transmitted from the mobile station to the selected base stations. The power level determining means may comprise means for adjusting the power level of signals transmitted from the mobile station to a selected base station, whereby a minimum signal power level for reaching a selected base station can be determined. Preferably, the power level determining means is adapted for determining the minimum signal power level based on signals received from the selected base station in response to the signals transmitted at a varying power level to the base station. The mobile station of the invention can be used as part of a system for locating a mobile station within a cellular communication system having a plurality of base stations, wherein the system further comprises location determining means for determining one or more possible locations of the mobile station based on the identities of the selected base stations and the determined corresponding minimum signal power levels. The location or position of the selected base station(s) may be determined from information based on the identity or identities of the selected base station(s), and the distance(s) between the mobile station and the selected base station(s) may be determined signal power levels.



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# A MOBILE STATION FOR USE AS A LOCATOR DEVICE WITHIN A CELLULAR COMMUNICATION SYSTEM

## FIELD OF THE INVENTION

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The present invention relates generally to cellular communication or telecommunication systems and, in particular, to a mobile station for collecting location data and to be used as a locator device within a cellular communication system.

## 10 BACKGROUND OF THE INVENTION

There are several areas in which it is desirable to have a service that can determine the location or position of a mobile unit operating within a cellular communication or telephone system. By having such a mobile unit, the unit may for example be  
15 mounted within different kind of objects such as a car, whereby the location of the objects can be monitored or the objects can be tracked, if somebody tries to steal the object. Furthermore, such a mobile unit can be used for navigating a driver of a car by providing information of the location of the car.

20 A major problem with existing solutions for locating mobile terminals or stations is the high cost and complexity required for their implementation into the existing cellular network infrastructure. Some solutions thus require extensive modifications to base stations or other components of a cellular communication system.

25 Different prior art solutions to the problem of locating a mobile station have been proposed and will be discussed briefly below.

U.S. Pat. No. 5,293,645 to Sood discloses a system and a method of locating a movable radio terminal within a cellular system. Here it is required that a plurality of  
30 base stations transmit synchronized timing reference signals. A receiver in the network receives a transmission from the radio terminal to be located that includes information compiled at the radio terminal indicating relative propagation delays in receipt of the timing reference signals from at least three base stations. A processor within the receiver converts the propagation delays into a geographic location of the  
35 radio terminal. A major disadvantage of this system is that the existing network must

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be modified to enable all the base stations to simultaneously transmit timing reference signals.

5 U.S. Pat. No. 5,924,040 to Trompower discloses a system for locating a mobile communication unit within a cellular system. Here the base stations have circuitry for varying the power level of signals transmitted to the mobile unit, whereby the cell coverage area of the base stations is changed and the location of the mobile unit may be determined. A major disadvantage of this system is that the existing base stations must be modified in order to incrementally change the signal power level.

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U.S. Pat. No. 5,613,205 to Dufour discloses a system for locating a mobile terminal within a cellular system, where the mobile terminal identifies several candidate handoff cells having sufficient signal strength to maintain a call. Then sequential handoffs is forced of the mobile station from a serving cell or base station to the  
15 handoff cells or base stations. The signal strengths and propagation delays between the mobile station and the serving base station and each handoff base station are measured, whereby the distances between the mobile station and cells may be calculated. Here, the signal strengths and the propagation delays are measured at the base stations, giving a drawback in that each base station needs to comprise circuitry in order to perform such calculations.  
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U.S. Pat. No. 5,943,014 to Gilhousen discloses a method of determining the position of a mobile station within a cellular telephone system having several base stations. Here, a signal is transmitted at a low power level from the mobile station and if  
25 the signal is received by several base stations, the location of the mobile station may be determined based on a time difference of the signals received by the base stations. If the signal is not received by several base stations, the mobile station retransmit the signal at increased power levels until the signal has been received by several base stations whereby one or more time differences are obtained and the  
30 position of the mobile station may be determined. The system disclosed by Gilhousen requires a synchronised system of base stations being adapted to perform the required calculations.

U.S. Pat. No. 5,903,844 to Bruckert discloses a method and a system for locating a  
35 remote unit within a wireless communication system. Here, a page signal is broad-

cast to the remote unit and the serving and neighbour base stations are determined. These base stations are instructed to tune receiving elements to obtain data transmitted by the remote unit during location. The serving base station then instructs the remote unit to periodically transmit a known message with increasing power levels  
5 for a predetermined number of times whereby the message may be received by several base neighbour base stations. The location of the remote unit may now be determined based on the time differences in the signals received at the base stations. Thus, the system of Bruckert also requires that base stations are synchronised during a location process and that the stations are adapted for performing the  
10 required calculations.

U.S. Pat. No. 5,208,756 to Song discloses a vehicle locating and navigating system using a cellular telephone network. Here, a mobile telephone device measures the signal strengths of control signals received from several base stations. The device  
15 then calculates the distance between the vehicle and each base station based on the measured signal strengths and the power level at which these signals are transmitted from the base stations. A major problem of this system is that the mobile telephone device needs to have information of the power levels of which the signals are transmitted from the base station. Such information may not always be forwarded from the base stations and it is suggested that the information may be  
20 stored in a memory in the mobile telephone device. However, if such information is pre-stored in the device, the memory has to be replaced or re-programmed whenever there are changes in the base station network.

25 It would therefore be a distinct advantage to have an improved mobile station which could be located within a cellular communication system without having any information of the power level of signals transmitted from the base stations, whereby the locating process could operate independently of changes in the base station network. Furthermore, it would also be an advantage if the locating process does  
30 not require base stations to transmit synchronised timing reference signals and does not require extensive modifications to the communication system infrastructure including the base stations.

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## SUMMARY OF THE INVENTION

In order to provide such an improved mobile station, the present invention in a first aspect provides a mobile station for use as a locator device within a cellular communication system or network having a plurality of base stations, said mobile station comprising:

identification means for identifying and selecting one or more base stations having sufficient signal strength to communicate with the mobile station, and

power level determining means for determining for one or more selected base stations corresponding minimum signal power levels for signals transmitted from the mobile station to the selected base stations.

According to a preferred embodiment of the present invention the power level determining means comprises means for adjusting the power level of signals transmitted from the mobile station to a selected base station. Thus, the mobile station may be adapted for controlling the power level of signals transmitted to selected base stations, whereby a minimum signal power level for reaching a selected base station can be determined. Preferably, the power level determining means is adapted for determining the minimum signal power level based on signals received from the selected base station in response to the signals transmitted at a varying power level to the base station. The mobile station may be adapted to or have means for adjusting or registering the power level of transmit signals in increments or steps.

Thus, the power level determining means may comprise request signal transmitting means for transmitting a series of request signals at a varying power level to a selected base station, and response signal receiving means for receiving a series of response signals being transmitted from the selected base station in response to the series of request signals, said power level determining means being adapted for determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

In order to reduce the number of possible locations points of the mobile station, it is preferred that the minimum signal-power level is determined for more than one base

station. Thus, the identification means may be adapted for identifying and selecting a first and a second base station having sufficient signal strength to communicate with the mobile station, and the power level determining means may be adapted for determining a first and a second minimum signal power level for signals transmitted from the mobile station to the first and the second base station, respectively. Here, the power level determining means may comprise means for adjusting the power level of a first and a second request signal or series of request signals transmitted from the mobile station to the first and the second base station, respectively. It is preferred that the power level determining means comprises: request signal transmitting means for transmitting a first and a second series of request signals at a varying signal power level to the first and the second base station, respectively, and response signal receiving means for receiving a first and a second series of response signals being transmitted from the first and the second base station, respectively, in response to the series of request signals, said power level determining means being adapted for determining the minimum signal power levels based on the received series of response signals and the power levels of the corresponding series of request signals.

Using three base stations may even further reduce the number of possible location points. So, in a preferred embodiment of the mobile station, the identification means is adapted for identifying and selecting a first, a second and a third base station having sufficient signal strength to communicate with the mobile station, and the power level determining means is adapted for determining a first, a second and a third minimum signal power level for signals transmitted from the mobile station to the first, the second and the third base station, respectively. Here, the power level determining means may comprise means for adjusting the power level of a first, a second and a third series of request signals transmitted from the mobile station to the first, the second and the third base station, respectively. Preferably, the power level determining means comprises: request signal transmitting means for transmitting a first, a second and a third series of request signals at a varying signal power level to the first, the second and the third base station, respectively, and response signal receiving means for receiving a first, a second and a third series of response signals being transmitted from the first, the second and the third base station, respectively, in response to the series of request signals, said power level determining means being adapted for determining the minimum signal power levels based on the

received series of response signals and the power levels of the corresponding series of request signals.

When receiving a response signal from a base station, the response signal may indicate if any errors were introduced during the transmission or not. A valid response signal may then be defined as any received response signal or as any response signal indicating an error free transmission. So, the power level determining means may be adapted for determining the minimum signal power level as a function of or based on the minimum power level at which a valid response signal is received from the selected base station in response to the signals transmitted from the mobile station. In one embodiment the minimum signal power level may be determined as the minimum power level at which a valid response signal is received from the selected base station. In an alternative embodiment of the invention, the power level determining means may be adapted for determining the minimum signal power level as the average power level of the signal with the lowest power level resulting in a valid response signal and the power level of the signal with the highest power level resulting in no response signal.

In order for the mobile station to identify any base station, the identification means may be adapted for collecting identity data of one or more of the selected base station.

The base stations may broadcast signals comprising identity data, so the identification means of the mobile station may be adapted for identifying said one or more base stations based on broadcast signals transmitted from said base station(s). In an embodiment of the invention, the identification means is adapted for identifying and selecting a first base station as the base station having a broadcast signal being received with the highest signal power level at the mobile station. The identification means may also be adapted for identifying and selecting a second base station as the base station having a broadcast signal being received with the second highest signal power level at the mobile station. Furthermore, the identification means may be adapted for identifying and selecting a third base station as the base station having a broadcast signal being received with the third highest signal power level at the mobile station. It should be understood that according to the present invention, other criteria may be used for selecting a first, a second and/or a third base station.



In order to store obtained data, the mobile station may comprise memory means for storing identity data corresponding to the one or more selected base station(s) and power level data corresponding to the determined minimum signal power level(s).

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The mobile station according to the invention may be used for collecting data to be used for locating the mobile station. The mobile station may therefore comprise message transmitting means for transmitting to a host computer or an operator one or more location messages including information based on the identity or identities of the selected base stations and the determined corresponding minimum signal power levels. Here, the message transmitting means may be adapted for transmitting said location message(s) via a serving base station to a host computer or an operator.

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In order to save electric power, it is preferred that the mobile station according to the invention is in a stand by or idle mode when not performing or being part of a location process. The location process may be started by a location request signal. So, the mobile station may be adapted to receive a location request signal, the receiving of said location request signal activating the mobile station. Here, the mobile phone may be adapted to activate the identification means and the power level determining means upon receiving the location request signal. The mobile phone may also be adapted to activate the message transmitting means upon receiving the location request signal. The mobile station may be adapted to be activated by receiving a location request signal forwarded from a host computer by use of one or more base stations, whereby the location request signal is transmitted via the cellular system or network. The mobile station may also or alternatively be adapted to be activated by receiving a location request signal forwarded from an alarm circuitry.

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The signals transmitted between the mobile station and the base stations may be transmitted using different channels. However, according to an embodiment of the invention, the signals transmitted from the mobile station to the selected base stations may comprise control-channel signals and/or traffic-channel signals. Similarly, the signals transmitted from the base stations to the mobile station may comprise control-channel signals and/or traffic-channel signals.

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It should be understood that several schemes or techniques may be used for determining the minimum signal power levels. According to an embodiment of the invention, the power level determining means of the mobile station may be adapted for determining a minimum signal power level by adjusting the power levels of the transmitted signals according to a technique from the group consisting of bisection, increasing power level, and decreasing power level.

It is preferred that the mobile station of the present invention is used as a part of a locating system. Thus, in a second aspect of the present invention there is provided a system for locating a mobile station within a cellular communication system or network having a plurality of base stations, said system comprising a mobile station according to any of the embodiments of the first aspect of the invention being adapted for transmitting location messages including information based on the identities of the selected base stations and the determined corresponding minimum signal power levels, and location determining means for determining one or more possible locations of the mobile station based on said location message(s).

The location determining means of the system may be adapted for determining the location or position of the selected base station(s) from the information based on the identity or identities of said base station(s), and for determining the distance(s) between the mobile station and the selected base station(s) from the information based on the obtained corresponding minimum signal power levels. According to an embodiment of the second aspect of the invention, the location determining means may be adapted for defining one or more arcs or circular arcs of possible locations of the mobile station, said arcs being centred on the location of the selected base station(s), and said arcs having a radius corresponding to the distance(s) between the mobile station and the respective base station(s). Thus, the location determining means may be adapted for calculating an intersection point of said arcs of possible locations. Here, the location determining means may be adapted for calculating the intersection point by using a geographic intersection technique from the group consisting of arculaction, triangulation, and defining a probability density function.

It is also within the scope of the present invention to provide an improved method of collecting location data. Thus, according to a third aspect of the present invention there is provided a method of collecting data for locating a mobile station within a

cellular communication system or network having a plurality of base stations, said method comprising the steps of: identifying and selecting at the mobile station one or more base stations having sufficient signal strength to communicate with the mobile station, and determining at the mobile station for one or more selected base stations corresponding minimum signal power levels for signals transmitted from the mobile station to the selected base stations. According to the method of the present invention the minimum signal power level may be determined by adjusting the power level of a series of signals transmitted from the mobile station to a selected base station. Thus, it is preferred that the mobile station comprises circuitry for communicating with the base stations and for adjusting the power level of signals transmitted to selected base stations.

The determination of a minimum signal power level may comprise the steps of: transmitting from the mobile station a series of request signals at a varying power level to a selected base station, receiving at the mobile station a series of response signals being transmitted from the selected base station in response to the request signals, and determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

Again, it is preferred to use more than one base station when determining possible points of location. So, according to an embodiment of the method of the invention, a first and a second base station having sufficient signal strength to communicate with the mobile station may be identified and selected at the mobile station, and a first and a second minimum signal power level for signals transmitted from the mobile station to the first and the second base station, respectively, may be determined at the mobile station. Here, the minimum signal power levels may be determined by adjusting the power level of a first and a second series of request signals transmitted from the mobile station to the first and the second base station, respectively. Preferably, the determination of the minimum signal power levels comprises: transmitting from the mobile station a first and a second series of request signals at a varying power level to the first and the second base station, respectively, receiving at the mobile station a first and a second series of response signals being transmitted from the first and the second base station, respectively, in response to the request signals, and determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

According to another embodiment of the method of the invention, a first, a second and a third base station having sufficient signal strength to communicate with the mobile station may be identified and selected at the mobile station, and a first, a second and a third minimum signal power level for signals transmitted from the mobile station to the first, the second and the third base station, respectively, may be determined at the mobile station. The minimum signal power levels may be determined by adjusting the power level of a first, a second and a third series of request signals transmitted from the mobile station to the first, the second and the third base station, respectively. Preferably, the determination of the minimum signal power levels comprises: transmitting from the mobile station a first, a second and a third series of request signals at a varying power level to the first, the second and the third base station, respectively, receiving at the mobile station a first, a second and a third series of response signals being transmitted from the first, the second and the third base station, respectively, in response to the request signals, and determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

The determination of a minimum signal power level may be done in several ways, but one method may comprise determining a minimum signal power level as a function of or based on the obtained minimum signal power level at which a valid response signal is received from the selected base station in response to the signals transmitted from the mobile station. Here, a valid response signal may be defined as any response signal received in response to a signal transmitted from the mobile station to the selected base station. Alternatively, a valid response signal may be defined as a response signal indicating an error free transmission. In one method the determined minimum signal power level is set equal to the obtained minimum signal power level at which a valid response signal is obtained. The method of the present invention also covers a method in which the minimum signal power level is determined as the average power level of the signal with the lowest power level resulting in a valid response signal, and the power level of the signal with the highest power level resulting in no response signal.

According to an embodiment of the method of the invention the identification of base stations may comprise collecting identity data of one or more base stations.

The identification of one or more base stations may be based on broadcast signals transmitted from the base station(s). In one embodiment the identification of one or more base stations comprises identifying and selecting a first base station as the base station having a broadcast signal being received with the highest signal power level at the mobile station. The identification of one or more base stations may also comprise identifying and selecting a second base station as the base station having a broadcast signal being received with the second highest signal power level at the mobile station. Furthermore, the identification of one or more base stations may comprise identifying and selecting a third base station as the base station having a broadcast signal being received with the third highest signal power level at the mobile station.

The method of the present invention may also comprise the step of storing within the mobile station one or more location messages based on the identity or identities of the selected base station(s) and the determined corresponding minimum signal power level(s).

In order to perform the final location procedure, the method of the present invention may also comprise the step of transmitting from the mobile station to a host computer or an operator one or more location messages including information based on the identity or identities of the selected base stations and the determined corresponding minimum signal power levels. The location message(s) may be transmitted via a serving base station to a host computer or an operator.

It is preferred that any of the present methods of collection data are initiated by a location request signal received at the mobile station. Such a location request signal may for example be forwarded from a host computer by use of one or more base stations within the cellular system or network, or it may be forwarded from an alarm circuitry.

For any of the methods of the present invention the signals transmitted from the mobile station to selected base stations may comprise control-channel signals and/or traffic-channel signals. Similarly, the signals transmitted from the selected base stations to the mobile station may comprise control-channel signals and/or traffic-channel signals.

As already mentioned different schemes or techniques may be used for determining the minimum signal power levels. Such techniques may according to any of the methods of the present invention comprise adjusting the power level of the signals transmitted from the mobile station to the selected base stations according to a technique from the group consisting of bisection, increasing power level, and decreasing power level.

It is preferred that the data collected in any of the methods of the third aspect of the invention is used for determining the location of the mobile station. Thus, according to a fourth aspect of the present invention, there is provided a method of locating a mobile station within a cellular communication system or network having a plurality of base stations, said method comprising the steps of collecting data according to any of the methods of the third aspect of the invention, and determining one or more possible locations of the mobile station based on the identity or identities of the selected base station(s) and the determined corresponding minimum signal power level(s).

Here, the determination of one more possible locations of the mobile station may comprise determining the location(s) of the selected base station(s) from information based on the identity of said base station(s), and determining the distance(s) between the mobile station and the selected base station(s) from the information based on the obtained corresponding minimum signal power level(s). Preferably, the determination of one more possible locations of the mobile station comprises determining one or more arcs or circular arcs of possible locations of the mobile station, said arcs being centred on the location of selected base station(s), and said arcs having a radius corresponding to the distance(s) between the mobile station and the respective base station(s). So, the determination of one more possible locations of the mobile station may comprise calculating an intersection point of said arcs of possible locations. It should be understood that the calculation of the intersection point(s) may be performed in several ways, but it is preferred that it is performed by using a geographic intersection technique from the group consisting of arculatation, triangulation, and defining a probability density function.

It should be understood that the mobile station of the present invention may be used for solving a plurality of locating tasks. Thus, a number of mobile stations according to the invention may be fixed to a number of objects or products, where an operator needs to know the locations of such objects or products. Such products could for example be cars for rental, photocopying machines for rental or containers for transport of goods.

It should also be understood that the mobile station of the present invention may also be used as part of a navigating system making use of a cellular communication network. When the location of the mobile station has been determined, a navigation message based on the determined location may be returned from the host computer or the operator to the mobile station. The mobile station may now provide navigation information based on the received navigation message to a user, whereby the user may be informed of the location. The user may for example be the driver of a car with the mobile station affixed to the car, and the navigation information may be forwarded to the user via a computer screen, where the determined location is shown on a map on the computer screen.

Other objects, features and advantages of the present invention will be more readily apparent from the detailed description of the preferred embodiments set forth below, taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a functional block diagram of a mobile station locating system in accordance with an embodiment of the present invention,

Fig. 2 is a flow chart illustrating the functions performed by the mobile station when performing a location process according to a preferred embodiment of the present invention,

Fig. 3 is a flow chart illustrating the functions performed by a system operator when performing the location process of Fig. 2,

Fig. 4 is a diagram illustrating a search map constructed in accordance with the teachings of a preferred embodiment of the present invention, and

Fig. 5 is a block diagram of the mobile station in accordance with a preferred embodiment of the present invention.

#### DESCRIPTION OF PREFERRED EMBODIMENT

A functional block diagram of a mobile station locating system in accordance with a preferred embodiment of the present invention is illustrated in Fig. 1. The system of Fig. 1 comprises a standard cellular system in accordance with the GSM standards, where GSM stands for Global System for Mobile communication. A block 10 represents the Public Switched Telephone Network, PSTN, and is shown connected to a block 12 designated as a Mobile Switching Centre, MSC. The MSC 12 is shown connected to three BSC (base station controller) blocks 14, 16 and 18. Although each BSC would be connected to and control a plurality of BSTs (Base Station or Base Station Transceiver)s, only three BSTs are shown connected to BSC 16, where the three BSTs are designated as 20, 22 and 24. Each BST represents a cell in the cellular system.

A mobile station MS 30 according to the present invention is shown within the cell of BST 20. It should be understood that normally the mobile station 30 will receive signals from BST 20 with the highest signal power levels, but the mobile station 30 will also be able to communicate via a number of other BSTs, although the signals from such BSTs will be received at a lower power level.

Here it should be understood that the mobile station MS of the preferred embodiment of the present invention is able to communicate within the cellular network of Fig. 1 by use of the same functions as a normal mobile phone or station. However, an embodiment the mobile station may be adapted to only communicate data, since the communication of speech signals may not be needed.

By use of the cellular system of Fig. 1, the mobile station MS is able to communicate with virtually any telephone station in the world. Thus, by communicating via the



cellular system the mobile station MS may communicate with an operator having a mobile phone, a fixed telephone or a computer, which may be a host computer.

5 A service unique to GSM is the Short Message Service, SMS, which allows users to send and receive point-to-point alphanumeric messages up to a few tens of bytes. It is similar to paging services, but much more comprehensive, allowing bi-directional messages, store-and-forward delivery, and acknowledgement of successful delivery.

10 More detailed information on the structure and functioning of the GSM system can be obtained from the public available GSM specifications, which are well known to those skilled in the art. However, an introduction to the GSM system may be found in the publications "The GSM System", Version 1,11, by Christian Pagh, "Overview of the Global System for Mobile Communications", by John Scourias, University of Waterloo, and "An overview of the GSM system" by Javier Gozávez Sempere, Uni-  
15 versity of Strathclyde, Glasgow, Scotland. These publications are all made public available via the Internet.

20 In the GSM system groups of cells can be arranged together as respective "Location Areas" with all the cells within a particular Location Area being arranged to broadcast the same Location Area Identity signal, LAI. When the MS is powered on or enters a cell in a new Location Area, it performs a standard location update procedure, in which it receives the LAI from the base station, BST, of the cell in which it is located and, in response to this, transmits an identifying signal back to the base station. In this way the network knows the Location Area in which the MS is positioned,  
25 although the actual cell in which the mobile station is positioned is not known. During the location update procedure the MS indicates its IMSI, International Mobile Subscriber Identity, to the network. The first of such a normal location update procedure is called the IMSI attach procedure.

30 In the following is given a summary of signals exchanged between the mobile station MS and a base station BST. Such signal exchange may include a location update procedure:

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#### SIGNALS BROADCASTED FROM BASE STATIONS

When the MS is powered on it starts listening to signals from the base stations, BSTs. These signals are received on broadcast channels, BCH. Each BST continually broadcast downlink information on a broadcast control channel, BCCH, which  
5 information includes base station identity BSTID, location area identity LAI, frequency allocations, and frequency hopping sequences. On the frequency correction channel, FCCH, and the synchronisation channel, SCH, information is received from the BST which is used to synchronise the MS to the time slot structure of a cell by defining the beginning of a TDMA frame.

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#### MOBILE STATION GENERATES A LIST OF BASE STATIONS WITH SIGNAL POWER LEVELS

Based on the signals received on the FCCH, the MS may store information to obtain a list of the base stations, which may be used for communication. The list comprises  
15 information of the power levels of the received signals PLRS together with the base station identity BSTID.

#### MOBILE STATION SELECTS A BASE STATION

Based on the stored list the MS selects a base station in order to obtain access to the network. It is preferred that the first selected base station is the base station  
20 having the highest power level PLRS.

#### MOBILE STATION CHANNEL REQUEST

Based on signals received on the broadcast channels from the selected BST, the MS transmits a request access signal to the selected BST. The signal is transmitted  
25 on a random access channel, RACH. Following the request on the RACH, the BST forwards a signal on an access grant channel, AGCH, whereby a stand-alone dedicated control channel, SDCCH, is allocated to the MS. By the allocating of a SDCCH data may be communicated between the network and the MS.

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#### MOBILE STATION LOGGING ON THE NETWORK

The MS now performs a registration procedure called "IMSI attach procedure", where IMSI stands for International Mobile Subscriber Identity, in which the MS is identified to the network. The registration procedure may also include the location

update procedure. When the MS has been logged on the network, the MS turns into idle mode and the SDCCH is no longer allocated the MS.

#### MOBILE STATION ON THE NETWORK

- 5 Now the network has accepted the MS and the LAI is known, making it possible for incoming call signals to reach the MS. The MS is in idle mode, and if a subscriber wants to reach the MS, a paging signal is forwarded through the network via the BST on the paging channel, PCH, whereby the MS is alerted of the incoming call and shifts to dedicated mode. If the MS wants to make a call, a signal is forwarded  
10 from the MS on the RACH and the MS shifts into dedicated mode.

#### MOBILE STATION LOGGIN OFF THE NETWORK

- When the MS is powered off an "IMSI detach procedure" is performed, whereby the network is informed that the MS is turned off. Thus, the network needs not transmit  
15 any paging signals if an incoming call is received.

- It should be understood that although the GSM network represents a preferred network, the principles of the present invention may be used in any other cellular communication system, such as the USDC system, United States Digital Cellular system.  
20

- According to the present invention the MS is adapted or programmed to determine a minimum signal power level, MSPL, of signals transmitted from the MS to a selected BST. In the preferred embodiment, the cellular network is the GSM network, and  
25 here a number of different channels such as RACH, SDCCH or TCH (traffic channels) may be used for transmitting signals of which the minimum signal power levels are to be determined.

- In the following an example is described in which the signals are transmitted using the RACH.  
30

The MS gets activated and listens to broadcast signals from base stations BSTs. A list of BSTs with received signal power levels PLRS is created and stored, and from this list a base station is selected. The MS now starts the procedure of determining

the minimum signal power level of signals transmitted from the MS to the selected BST using the RACH.

5 In order to determine the minimum signal power level, MSPL, the MS is adapted or programmed to transmit signals on the RACH at different power levels. The power levels of the transmitted signals may be varied in different ways. Thus, signals may be transmitted at increased power levels until a signal is received in return from the BST. The power level of the signals transmitted from the MS may be varied according to any other convenient scheme, such as starting with the highest power level and decreasing the power level, or using a scheme called bisection to be described later.

15 When using an increase in the power level as a method to determine the minimum power level, the MS transmits a first signal or a first series of signals at a minimum transmit power level on the RACH to the selected BST. There are 3 possibilities of getting a response signal or series of signals from the BST:

- 1) No response signal(s) is/are received at the MS. The power level of the transmitted signal(s) is/are too low.
- 20 2) A response signal or series of signals is/are received, but the received response signal(s) indicate that errors were introduced during the transmission of signal(s) from the MS to the BST. Here the MS may close down the transmission, register that the transmitted signal(s) reached the BST and store the power level of the transmitted signal or series of signals. The stored power level may now be used as the determined minimum signal power level, MSPL.
- 25 3) A response signal or series of signals is/are received, and the BST send the response signal(s) using the AGCH and allocates a SDCCCH to the MS. The MS may close down the transmission, register that the transmitted signal(s) reached the BST and store the power level of the transmitted signal or series of signals. The stored power level may now be used as the determined minimum signal power level, MSPL.
- 30
- 35

It is preferred that the minimum transmit power is set so low that the BST must be within a distance of only a few meters to receive the MS signal and send a response signal. If no response signal(s) is/are obtained from the first transmitted signal(s), the MS transmits a second signal or series of signals, where the power level  
5 is increased by one step. If no response signal(s) is/are received, the MS increase the power level one more step and transmits a third signal or series of signals.

The MS repeats increasing the power level of the transmit signals one step until a response signal or series of signals is/are obtained from the BST. It is preferred that  
10 the minimum power level, MSPL, is determined as the power level resulting in the first received response signal or series of signals. The first received response signal may be either a response signal indicating an error in the transmission or a response signal indicating an error free transmission, see possibilities 2 and 3.

15 In another embodiment of the invention, the MSPL is determined as the power level resulting in the first received response signal indicating an error free transmission from the MS to the BST.

In the above described example the signals are transmitted using the RACH.  
20 However, the above described determination of a MSPL may be performed when a channel has been allocated to the MS. Thus, the signals may be communicated by use of a SDCCCH or a TCH instead of the RACH.

If the MS starts the power level determination by using the highest power level, the  
25 following signal or series of signals are transmitted at a power level one step lower and so on. Here, the power level of the last signals giving any response signal from the BST may determine the MSPL. Alternatively, the power level of the last signals giving a response indicating an error free transmission may determine the MSPL.

30 In an alternative embodiment of the invention, the MSPL is determined as the average power level of the signal with the lowest power level resulting in a response signal and the power level of the signal with the highest power level resulting in no response signal.

In Fig. 2 is shown a flow chart illustrating the functions performed by the mobile station MS when performing a location process according to a preferred embodiment of the present invention. Beginning at step 1, the MS is in idle mode and no location process is performed. When a location process is to be initiated, an SMS message or a call comprising an operator location request is transmitted to the MS, see steps 2 and 3. It should be noted that the location process may also be initiated without sending a signal or message through the cellular network. Thus, the MS may be connected to an alarm circuitry, and an alarm signal given from such circuitry may start a location process. If the MS has been activated by a message or call from the network, a connection has been established and the MS shifted from idle to dedicated mode in step 3. In order to proceed the location process, the MS lay down the established connection, shifts to idle mode and goes to step 4.

In step 4, the MS starts the location process and proceeds to step 5 in order to register a number of near by BSTs to obtain a list of base stations, which may be used for communication. If no base station broadcast signals are received, the process moves to step 6 and the MS waits for 10 minutes before returning to step 4. If base station broadcast signals are received at step 5, the process proceeds to step 7, where the MS stores a list comprising information of the power levels of the received BST broadcast signals together with the identity of the base stations. From the obtained list, the MS selects three base stations based on the power level of the received signals, with the first, the second and the third base station corresponding to the highest, the second highest and the third highest power level of received signals, respectively. If only one or two base stations have a signal power level high enough to reach the MS, the location process will proceed based on this or these base stations.

When the first base station is selected, the process proceeds to step 8, in which step a first minimum signal power level, MSPL, of signals transmitted from the MS to the first selected base station is determined according to any of the herein described methods. When the first MSPL has been determined, the MS stores a first data set comprising information of the first base station identity, ID, and the obtained first MSPL, in a data package, see step 14. When the first data set has been stored, the process proceeds to step 9. If no other base stations are listed, the process moves

to step 13, but if the list comprises further base stations, the second base station is selected and the process moves to step 10.

5 At step 10 a second minimum signal power level, MSPL, of signals transmitted from the MS to the second selected base station is determined according to any of the above described methods. When the second MSPL has been determined, the MS stores a second data set comprising information of the second base station identity, ID, and the obtained second MSPL, in the data package, see step 14. When the second data set has been stored, the process proceeds to step 11. If no further  
10 base stations are listed, the process moves to step 13, but if the list comprises further base stations, the third base station is selected and the process moves to step 12.

At step 12 a third minimum signal power level, MSPL, of signals transmitted from the  
15 MS to the third selected base station is determined according to any of the above-described methods. When the third MSPL has been determined, the MS stores a third data set comprising information of the third base station identity, ID, and the obtained third MSPL, in the data package, see step 14. From step 14 the process moves to step 13 in which step the data package comprising information of the base  
20 station identities and the corresponding minimum signal power levels, MSPL, is forwarded via the network to an operator as a SMS message or package. When the SMS message or packet has been forwarded, the process moves to step 1 and the MS is turned into idle mode waiting for a new location request.

25 Here it should be noted that the data package may be forwarded to the operator using any other data transmission services within the network than the SMS service.

A system operator forwarding a location request signal as already mentioned may initiate the location process. In return to the location request signal, the operator  
30 receives via the cellular network a message or data package comprising information of the base station identities and the corresponding determined minimum signal power levels. Based on the received data package or message the operator may now determine the location of the mobile station MS.

Fig. 3 shows a flow chart illustrating the functions performed by a system operator during the location process. In step B1 the location process is started by forwarding a location request signal via the network to the MS. In step B2 the operator receives the data package comprising location information, and the process moves to step B3 in which the location of the MS is calculated. In a preferred embodiment the location is calculated by use of a well-known triangulation technique. When the location of the MS has been calculated, the process may stop at step B4 or move back to step B3 for performing another location process. Such a further location process may be needed if for example the MS is placed in a moving car or vehicle.

In Fig. 4 is shown a diagram illustrating a search map constructed in accordance with the teachings of a preferred embodiment of the present invention. Here, the operator determines the position of the base stations based on the base station identities, IDs. Information can be obtained from the network provider giving the base station locations together with the IDs, and the operator may store such information in a table, whereby the base station locations may be found by a table look up. The base station location or position may be given by the latitude and the longitude of the base station. The operator now calculates the distance from the mobile station MS to each of the base stations from the determined minimum signal power levels. Circles or arcs having centres at the position of the base stations and radius equal to the corresponding distance from the base station to the mobile station can now be drawn or calculated. The intersection point or points of these circles or arcs defines the location or points of possible locations of the mobile station MS.

The diagram of Fig. 4 shows a triangulation using three base stations. However, it is also within the present invention to use four or more base station in the location process. Thus, base station IDs and MSPL may be obtained for four or more base stations and used for calculating four or more circles or arcs, whereby the location of the MS may be determined to a higher accuracy. If only one base station can be reached from the MS, the location determination results in one circle of possible locations, whereas when two base stations can be reached, the two intersection points of the two circles indicates two possible locations of the MS. However, in order to obtain one common intersection point of location, at least three base stations are needed as shown in Fig. 4.



According to an embodiment of the present invention, the mobile station MS is built to transmit signals at a power level, which may be adjusted from 0-8 Watt. The value of the power level may be stored using a 12-bit address register with each address corresponding to a specific power level. Thus, the power level is given with a resolution of 4096 steps, and the power level may be expressed as a number of steps out of a total number of 4096. When the MSPL of a selected base station BST has been determined, the distance from the base station to the mobile station MS may be found using the equation:

$$\text{Distance}(\text{BST-MS}) = [\text{MSPL}(\text{given in number of steps})/4096] \times (\text{BST-factor}).$$

Here the base station factor, BST-factor, depends on the area in which the base station is located, for example whether it is located on an open field or in a city area. The BST-factor can be determined based on the base station ID.

When determining the location of the MS according to any of the embodiments of the present invention, the location may be determined by some degree of uncertainty. The uncertainty may arise from attenuation of the signals transmitted from the MS. Buildings or trees may for example attenuate the signals. The weather condition may also have an influence as fog or snow may also result in attenuation of the signals. Thus, in some cases a certain power level may result in an error free response signal, while in other cases the response signal may indicate an error, or no response signal is obtained at all. Furthermore, if the MS is placed on a moving object, the location may be changed before the location process is finished.

The degree of uncertainty may also be influenced by the choice of antenna for the mobile station. If a straight antenna is used a symmetric radiation can only be achieved when the antenna is pointing directly upwards, while a twisted antenna may result in a substantially symmetric radiation in several positions. Thus, according to one embodiment of the invention, it is preferred to use a straight antenna, while in another embodiment it is preferred to use a twisted antenna.

As already mentioned, according to an embodiment of the present invention the minimum signal power level, MSPL, may be determined by adjusting the power level of transmitted signals following a bisection technique. By bisection is meant dividing

into halves. In the following example, the power level is given in steps with a maximum of 4096 steps corresponding to 12 bits resolution. The power level shall be determined to a precision better than 1%, corresponding to 40 steps.

5      Example of bisection:

- Power level set to 2048. Response signal received. Precision 2048.
  - Power level set to 1024. No response signal received. Precision 1024.
  - Power level set to 1536. Response signal received. Precision 512.
  - 10          -            Power level set to 1280. Response signal received. Precision 256.
  - Power level set to 1152. Response signal received. Precision 128.
  - Power level set to 1088. No response signal received. Precision 64.
  - Power level set to 1120. No response signal received. Precision 32.
- 15          The power level of the last signal is too low, and the precision is 32 steps, which is less than the required 40 steps. The lowest power level giving a response signal is 1152 steps. The MSPL may now be determined as the average of the two determining numbers, 1152 and 1120, resulting in a value of 1136 steps. By using a bisection technique, the number of changes in the power level of the transmitted signals will always be the same for a required precision, which may be considered an advantage.
- 20

Fig. 5 is a block diagram illustrating a mobile station according to an embodiment of the present invention. The mobile station of Fig. 5 is based on the AD6421/AD6422  
 25          chipset from Analog Devices with a further control CPU. Thus, the embodiment of a mobile station of the present invention as illustrated in Fig. 5 may be described as a standard GSM mobile telephone with an add-on module, where the functionality of the GSM phone is well known to those skilled in the art. A mobile station according to the present invention may also be based on other known chipsets such as the  
 30          Othello chipset from Analog Devices or the MAX 2360 from Maxim.

The functionality of the AD6421/AD6422 chipset is discussed in the following with reference to the diagram of Fig. 5.

*GSM Processor (GSMP, 51)*

The AD6422 combines application specific hardware, an embedded 16-bit DSP and an embedded 16-bit microcontroller (Hitachi H8/300H). It performs channel coding and decoding, and executes the protocol stack and user software. The DSP implements full rate speech transcoding according to GSM specifications, including Discontinuous Transmission (DTX) and Comfort Noise Insertion (CNI). The embedded microcontroller executes the Layer 1, 2, 3 and user MMI software. The required Layer 1-software is supplied with the chipset. To ensure minimum power-consumption, the GSMP 51 has been designed to control all the power-down functions of the other components in the handset.

*Voiceband/Baseband Converter (VBC, 52)*

The AD6421 performs the voiceband and baseband analog-to-digital and digital-to-analog conversions, interfacing the digital sections of the chipset to the radio section. In addition to containing the VBC 52, the AD6421 also contains all the auxiliary converters for burst-ramping, AFC (automatic frequency control) 54 and 55, AGC (automatic gain control) 56, battery and temperature monitoring. The chipset interfaces directly with the radio and supplies all the synthesizer and timing control signals required to support two synthesizers and a variety of radio architectures including the AD6450 GSM RF-Chipset. The data is encrypted using the required A5/1 or A5/2 encryption algorithm. Data is then formatted into bursts, with the required timing and training sequences, and sent to the VBC 52 through a dedicated serial port 53. When a data message is to be transmitted from the mobile station, the encrypted data is forwarded via the VBC 52 through a filter 70, through a dedicated power amplifier 57 and to an antenna 58.

The AD6421 also comprises a sub digital to analog converter, SUB DAC 69, which will not be further discussed here.

The GSMP 51 and the VBC 52 perform a number of functions that is essential to build a complete mobile radio. A general radio section constitutes the three functions of transmitter, receiver and synthesizer. The baseband chipset interfaces to a typical radio architecture. The transmitter is fed with baseband analog I and Q signals from the VBC 52 and up converted to 900 MHz for GSM applications and 1800 MHz for PCN applications.

The dedicated power amplifier 57 increases the radio frequency RF output signal to the required level. The receiver receives incoming signal via the antenna 58, amplifies the antenna signal via a low noise amplifier LNA 59, sends the signal through a  
5 filter 60 and down-converts it to an intermediate frequency via an intermediate frequency stage IF 61 and amplifies it there again. After second conversion to baseband the I and Q components of the signal are fed into the VBC 52. The three auxiliary functions, AGC, AFC and Power Ramping are included to interface to the radio section.

10

#### *Power Ramp Envelope*

To meet the spectral and time-domain specifications of the transmitted output signal, the burst has to follow a specified power envelope. According to the present invention the envelope for the power profile is stored in a control CPU, Tx Control CPU  
15 62, which is an add-on component to the AD6421/AD6422 chipset. In a preferred embodiment the CPU 62 is an ARM 710T, but any other convenient CPU may be used. The envelope for the power profile originates from the TX Control CPU 62 as a set of coefficients, which are downloaded and stored in a RAM of the VBC 52. This envelope profile is fed via the serial ports of the VBC 53 to a memory RAMP  
20 RAM 63 giving a 12-bit signal to a RAMP DAC (digital to analog converter) 64 with each burst. The analog output is fed into the RF power amplifier 57, controlling the power profile and absolute level of the transmitted data. The power control loop of the power amplifier can also feedback an error control signal PAERROR 65 that indicates whether the output functions are out of specification and the radio can be  
25 switched off accordingly.

#### *Automatic Gain Control (AGC, 56)*

The mobile radio has to cope with a wide range of input signal levels. The major part of the overall gain is provided in the IF amplifier 61. The incoming signal level is  
30 analyzed in the GSMP 51 and a digital gain control signal is sent to the VBC 52. An AGC DAC generates the appropriate analog control signal for the IF amplifier 61.

#### *Automatic Frequency Control (AFC, 54 and 55)*

The mobile radio tracks the master clock provided by the base station to compensate for temperature/frequency drifts in a crystal oscillator VCTXCO 66. Drift of the  
35

crystal oscillator over time and temperature has to be compensated as well as frequency shifts due to the Doppler effect in the case of a moving mobile radio. The received signal is analyzed in the GSMP 51 and a digital control signal is generated. This signal is sent to the AFC DAC 55 in the VBC 52 to control the voltage controlled, temperature compensated crystal oscillator VCTCXO 66.

#### *Synthesizer Control*

The GSMP 51 and the respective parts of the Layer 1 software control the overall timing and frequency generation of the radio subsystem. This includes control signals for two synthesizers 67, power-down control signals and power amplifier monitor signals.

#### *Power dissipation considerations*

In mobile applications, minimizing the power consumption of all devices is critical to achieve longer standby times. In a GSM handset the baseband subsystem dominates the current consumption in standby. The design of the GSMP 51 and VBC 52 includes extensive features to reduce power consumption and give standby times of up to 100 hours. Both devices are specifically designed to operate from 2.7 V to 3.3 V, to enable three or four cell battery designs. The GSMP incorporates intelligent power management, permitting automatic control of power consumption in the Channel Codec part of the GSMP and the peripheral circuitry. Data processing modules are switched on only when they process data otherwise they are powered down. Additional control signals are provided that enable the Layer 1 software to control the external subsystems, such as the VBC 52, the radio and memory components, so that the GSMP 51 intelligently controls the power of these components. In the VBC 52, the power-down functions are split separately among receive, transmit and auxiliary circuits. It should be understood that even higher standby times up to 1000 hours might be achieved by use of newer chipsets such as the Othello chipset.

#### *Mobile station used as a locator device according to the present invention*

When the AD6421/AD6422 chipset is used as a standard GSM mobile telephone which is not adapted to be used as a locator device according to the present invention, the CPU 62 is not part of the telephone, and a standard power envelope is stored in the GSMP 51 from where it is forwarded to the VBC 52, the serial port 53,

the RAMP RAM 63, the RAMP DAC 64 to control the power level of a transmitted signal.

5 In the mobile station of the present invention as illustrated in Fig. 5 a user specified power profile envelope is needed. Here, the Tx Control CPU 62 comprises the required user specified power profile envelope and a control program for adjusting the power level of transmitted signals according to any convenient method for determining a minimum signal power level, including any of the above described methods, thereby including the bisection technique. The RAMP RAM 63 outputs a 12-bit  
10 signal whereby a resolution of the 4096 steps can be obtained for the power level.

When the mobile station of Fig. 5 receives signals, such as the location request signals and base station response signals, and when outgoing signals are to be transmitted, such as the request signals and the location messages, the mobile station  
15 operates as a standard GSM phone.

It should be understood that for the mobile station of Fig. 5 the Tx Control CPU 62 may comprise the user specified control software or programs needed for collecting data to be used for locating the mobile station and for transmitting such data as one  
20 or more location messages to a host computer.

Thus, the software needed for changing a standard GSM phone based on the above-described chipset to a mobile station according to the present invention may be stored in the added Tx Control CPU 62.  
25

While the invention has been particularly shown and described with reference to particular embodiments, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention, and it is intended that such changes come within the  
30 scope of the following claims.

## CLAIMS

1. A mobile station for use as a locator device within a cellular communication system having a plurality of base stations, said mobile station comprising:  
5 identification means for identifying and selecting one or more base stations having sufficient signal strength to communicate with the mobile station, and  
power level determining means for determining for one or more selected base stations corresponding minimum signal power levels for signals transmitted from the mobile station to the selected base stations.  
10
2. A mobile station according to claim 1, wherein the power level determining means comprises means for adjusting the power level of signals transmitted from the mobile station to a selected base station.  
15
3. A mobile station according to claim 1 or 2, wherein the power level determining means comprises:  
request signal transmitting means for transmitting a series of request signals at a varying power level to a selected base station, and  
20 response signal receiving means for receiving a series of response signals being transmitted from the selected base station in response to the request signals, said power level determining means being adapted for determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.  
25
4. A mobile station according to any of the claims 1-3, wherein the identification means is adapted for identifying and selecting a first and a second base station having sufficient signal strength to communicate with the mobile station, and  
the power level determining means is adapted for determining a first  
30 and a second minimum signal power level for signals transmitted from the mobile station to the first and the second base station, respectively.
5. A mobile station according to claim 4, wherein said power level determining means comprises means for adjusting the power level of a first and a second

series of request signals transmitted from the mobile station to the first and the second base station, respectively.

6. A mobile station according to claim 4 or 5, wherein said power level  
5 determining means comprises:

request signal transmitting means for transmitting a first and a second series of request signals at a varying signal power level to the first and the second base station, respectively, and

10 response signal receiving means for receiving a first and a second series of response signals being transmitted from the first and the second base station, respectively, in response to the series of request signals, said power level determining means being adapted for determining the minimum signal power levels based on the received series of response signals and the power levels of the corresponding series of request signals.

15

7. A mobile station according to any of the claims 1-6, wherein the identification means is adapted for identifying and selecting a first, a second and a third base station having sufficient signal strength to communicate with the mobile station, and

20

the power level determining means is adapted for determining a first, a second and a third minimum signal power level for signals transmitted from the mobile station to the first, the second and the third base station, respectively.

8. A mobile station according to claim 7, wherein said power level determining means comprises means for adjusting the power level of a first, a second  
25 and a third series of request signals transmitted from the mobile station to the first, the second and the third base station, respectively.

9. A mobile station according to claim 7 or 8, wherein said power level  
30 determining means comprises:

request signal transmitting means for transmitting a first, a second and a third series of request signals at a varying signal power level to the first, the second and the third base station, respectively, and

35 response signal receiving means for receiving a first, a second and a third series of response signals being transmitted from the first, the second and the



third base station, respectively, in response to the series of request signals, said power level determining means being adapted for determining the minimum signal power levels based on the received series of response signals and the power levels of the corresponding series of request signals.

5

10. A mobile station according to any of the claims 1-9, wherein the power level determining means is adapted for determining the minimum signal power level as the minimum power level at which a valid response signal is received from the selected base station in response to the signals transmitted from the mobile station.

10

11. A mobile station according to claim 10, wherein any response signal received in response to a signal transmitted from the mobile station to the selected base station is a valid signal.

15

12. A mobile station according to claim 10, wherein a valid response signal is an error free response signal.

13. A mobile station according to any of the claims 1-12, wherein the identification means is adapted for collecting identity data of one or more of the selected base station.

20

14. A mobile station according to any of the claims 1-13, wherein the identification means is adapted for identifying said one or more base stations based on broadcast signals transmitted from said base station(s).

25

15. A mobile station according to claim 14, wherein the identification means is adapted for identifying and selecting a first base station as the base station having a broadcast signal being received with the highest signal power level at the mobile station.

30

16. A mobile station according to claim 14 or 15, wherein the identification means is adapted for identifying and selecting a second base station as the base station having a broadcast signal being received with the second highest signal power level at the mobile station.

35

17. A mobile station according to any of the claims 14-16, wherein the identification means is adapted for identifying and selecting a third base station as the base station having a broadcast signal being received with the third highest signal power level at the mobile station.
- 5 18. A mobile station according to any of the claims 1-17, wherein the mobile station further comprises memory means for storing identity data corresponding to the one or more selected base station(s) and power level data corresponding to the determined minimum signal power level(s).
- 10 19. A mobile station according to any of the claims 1-18, wherein said mobile station further comprises  
message transmitting means for transmitting to a host computer or an operator one or more location messages including information based on the identity or identities of the selected base stations and the determined corresponding minimum signal power levels.
- 15 20. A mobile station according to claim 19, wherein the message transmitting means is adapted for transmitting said location message(s) via a serving base station to a host computer or an operator.
- 20 21. A mobile station according to any of the claims 1-20, wherein the mobile station is adapted to receive a location request signal, the receiving of said location request signal activating the mobile station.
- 25 22. A mobile station according to claim 21, wherein the mobile phone is adapted to activate the identification means and the power level determining means upon receiving said location request signal.
- 30 23. A mobile phone according to claim 22 and 10, wherein the mobile phone is further adapted to activate said message transmitting means upon receiving said location request signal.

24. A mobile station according to any of the claims 21-23, wherein the mobile station is adapted to be activated by receiving a location request signal forwarded from a host computer by use of one or more base stations.
- 5 25. A mobile station according to any of the claims 21-24, wherein the mobile station is adapted to be activated by receiving a location request signal forwarded from an alarm circuitry.
26. A mobile station according to any of the claims 1-25, wherein the signals transmitted from the mobile station to the selected base stations comprises control-channel signals and/or traffic-channel signals.
- 10 27. A mobile station according to any of the claims 1-26, wherein signals transmitted from the base stations to the mobile station comprises control-channel signals and/or traffic-channel signals.
- 15 28. A mobile station according to any of the claims 1-27, wherein the power level determining means is adapted for determining a minimum signal power level by adjusting the power levels of the transmitted signals according to a technique from the group consisting of bisection, increasing power level, and decreasing power level.
- 20 29. A system for locating a mobile station within a cellular communication system having a plurality of base stations, said system comprising a mobile station according to any of the claims 19-28, and location determining means for determining one or more possible locations of the mobile station based on said location message(s).
- 25 30. A system according to claim 29, wherein said location determining means is adapted for determining the location or position of the selected base station(s) from the information based on the identity or identities of said base station(s), and for determining the distance(s) between the mobile station and the selected base station(s) from the information based on the obtained corresponding minimum signal power levels.
- 30 35

31. A system according to claim 30, wherein the location determining means is adapted for defining one or more arcs or circular arcs of possible locations of the mobile station, said arcs being centred on the location of the selected base station(s), and said arcs having a radius corresponding to the distance(s) between the mobile station and the respective base station(s).

32. A system according to claim 31, wherein the location determining means is adapted for calculating an intersection point of said arcs of possible locations.

33. A system according to claim 32, wherein the location determining means is adapted for calculating the intersection point by using a geographic intersection technique from the group consisting of arculature, triangulation, and defining a probability density function.

34. A method of collecting data for locating a mobile station within a cellular communication system having a plurality of base stations, said method comprising the steps of:

identifying and selecting at the mobile station one or more base stations having sufficient signal strength to communicate with the mobile station, and determining at the mobile station for one or more selected base stations corresponding minimum signal power levels for signals transmitted from the mobile station to the selected base stations.

35. A method according to claim 34, wherein a minimum signal power level is determined by adjusting the power level of a series of signals transmitted from the mobile station to a selected base station.

36. A method according to claim 34 or 35, wherein the determination of a minimum signal power level comprises:

transmitting from the mobile station a series of request signals at a varying power level to a selected base station,

receiving at the mobile station a series of response signals being transmitted from the selected base station in response to the request signals, and

determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

37. A method according to any of the claims 34-36, wherein  
5 a first and a second base station having sufficient signal strength to communicate with the mobile station is identified and selected at the mobile station, and  
a first and a second minimum signal power level for signals transmitted from the mobile station to the first and the second base station, respectively, is determined at the mobile station.  
10

38. A method according to claim 37, wherein the minimum signal power levels are determined by adjusting the power level of a first and a second series of request signals transmitted from the mobile station to the first and the second base station, respectively.  
15

39. A method according to claim 37 or 38, wherein determination of the minimum signal power levels comprises:  
transmitting from the mobile station a first and a second series of request signals at a varying power level to the first and the second base station, respectively,  
20 receiving at the mobile station a first and a second series of response signals being transmitted from the first and the second base station, respectively, in response to the request signals, and  
25 determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

40. A method according to any of the claims 34-39, wherein  
30 a first, a second and a third base station having sufficient signal strength to communicate with the mobile station is identified and selected at the mobile station, and  
a first, a second and a third minimum signal power level for signals transmitted from the mobile station to the first, the second and the third base station, respectively, is determined at the mobile station.  
35

41. A method according to claim 40, wherein the minimum signal power levels are determined by adjusting the power level of a first, a second and a third series of request signals transmitted from the mobile station to the first, the second and the third base station, respectively.

42. A method according to claim 40 or 41, wherein determination of the minimum signal power levels comprises:

transmitting from the mobile station a first, a second and a third series of request signals at a varying power level to the first, the second and the third base station, respectively,

receiving at the mobile station a first, a second and a third series of response signals being transmitted from the first, the second and the third base station, respectively, in response to the request signals, and

determining the minimum signal power level based on the received response signals and the power levels of the corresponding request signals.

43. A method according to any of the claims 34-42, wherein the mobile station comprise circuitry for communicating with the base stations and for adjusting the power level of signals transmitted to selected base stations.

44. A method according to any of the claims 34-43, wherein the determination of a minimum signal power level comprises

determining the minimum power level at which a valid response signal is received from the selected base station in response to the signals transmitted from the mobile station.

45. A method according to claim 44, wherein any response signal received in response to a signal transmitted from the mobile station to the selected base station is a valid signal.

46. A method according to claim 44, wherein a valid response signal is an error free response signal.

47. A method according to any of the claims 34-46, wherein the identification of base stations comprises collecting identity data of one or more base stations.

48. A method according to any of the claims 34-47, wherein the identification of one or more base stations is based on broadcast signals transmitted from the base station(s).

5

49. A method according to claim 48, wherein the identification of one or more base stations comprises identifying and selecting a first base station as the base station having a broadcast signal being received with the highest signal power level at the mobile station.

10

50. A method according to claim 48 or 49, wherein the identification of one or more base stations comprises identifying and selecting a second base station as the base station having a broadcast signal being received with the second highest signal power level at the mobile station.

15

51. A method according to any of the claims 48-50, wherein the identification of one or more base stations comprises identifying and selecting a third base station as the base station having a broadcast signal being received with the third highest signal power level at the mobile station.

20

52. A method according to any of the claims 34-51, said method further comprising  
storing within the mobile station one or more location messages based on the identity or identities of the selected base station(s) and the determined corresponding minimum signal power level(s).

25

53. A method according to any of the claims 34-52, said method further comprising  
transmitting from the mobile station to a host computer or an operator  
one or more location messages including information based on the identity or identities of the selected base stations and the determined corresponding minimum signal power levels.

30

54. A method according to claim 53, wherein the location message(s) is/are transmitted via a serving base station to a host computer or an operator.

35

55. A method according to any of the claims 34-54, wherein the data collection is initiated by a location request signal received at the mobile station.
- 5 56. A method according to claim 55, wherein the location request signal is forwarded from a host computer by use of one or more base stations.
57. A method according claim 55, wherein the location request signal is forwarded from an alarm circuitry.
- 10 58. A method according to any of the claims 34-57, wherein the signals transmitted from the mobile station to selected base stations comprises control-channel signals and/or traffic-channel signals.
- 15 59. A method according to any of the claims 34-58, wherein the signals transmitted from the selected base stations to the mobile station comprises control-channel signals and/or traffic-channel signals.
60. A method according to any of the claims 34-59, wherein the determination of a minimum signal power level comprises  
adjusting the power level of the signals transmitted from the mobile station to the selected base stations according to a technique from the group consisting of bisection, increasing power level, and decreasing power level.
- 25 61. A method of locating a mobile station within a cellular communication system having a plurality of base stations, said method comprising  
collecting data according to any of the claims 34-60, and  
determining one or more possible locations of the mobile station based on the identity or identities of the selected base station(s) and the determined corresponding minimum signal power level(s).
- 30 62. A method according to claim 61, wherein the determination of one or more possible locations of the mobile station comprises  
determining the location(s) of the selected base station(s) from information based on the identity of said base station(s), and
- 35



determining the distance(s) between the mobile station and the selected base station(s) from the information based on the obtained corresponding minimum signal power level(s).

- 5      63.      A method according to claim 62, wherein the determination of one more possible locations of the mobile station comprises

                                 determining one or more arcs or circular arcs of possible locations of the mobile station, said arcs being centred on the location of selected base station(s), and said arcs having a radius corresponding to the distance(s) between the  
10      mobile station and the respective base station(s).

64.      A method according to claim 63, wherein the determination of one more possible locations of the mobile station further comprises calculating an intersection point of said arcs of possible locations.

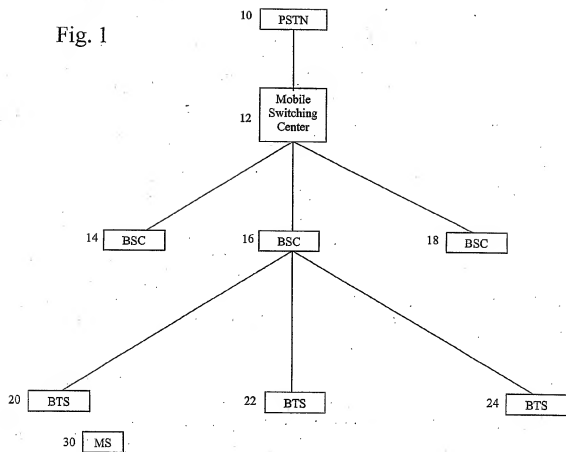
15

65.      A method according to claim 64, wherein the calculation of the intersection point is performed by using a geographic intersection technique from the group consisting of arculation, triangulation, and defining a probability density function.

20

1 / 5

Fig. 1



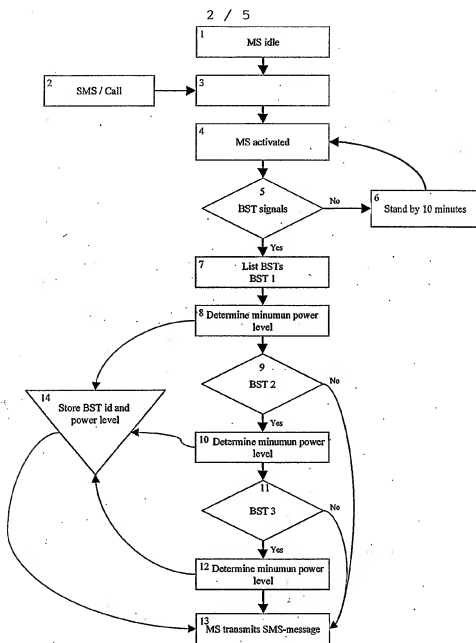


Fig. 2

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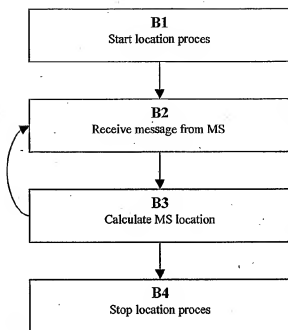
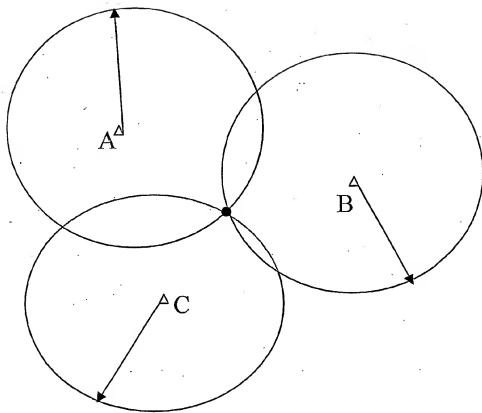


Fig. 3

Fig. 4



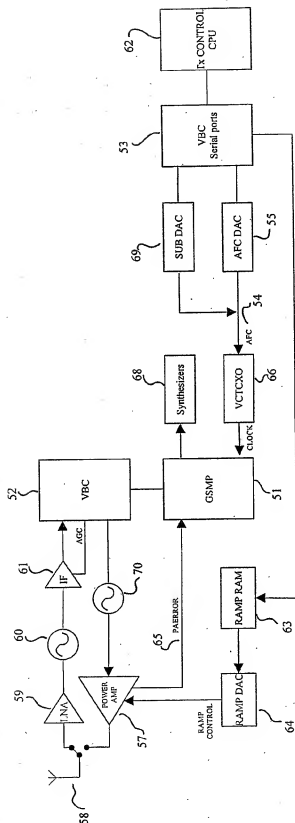


Fig. 5

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 01/00417

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04Q 7/38, H04Q 7/22

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, PAJ, FULLTEXT, INSPEC, EPOQUE

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5095500 A (DANIEL R. TAYLOR ET AL), 10 March 1992 (10.03.92), column 2, line 39 - line 68, figures 1-5, claims 1,12 --	1-2, 23, 29-30, 34-35
P, X	US 6212391 B1 (BILAL A. SALEH ET AL), 3 April 2001 (03.04.01), column 11, line 54 - column 16, line 46, figures 1-12 --	1-2, 23, 29-30, 34-35
A	US 5293645 A (PREM L. SOOD), 8 March 1994 (08.03.94), figures 1-6, abstract --	1-65
A	US 5924040 A (MICHAEL L. TROMPPOWER), 13 July 1999 (13.07.99), figures 1-2, 6-7, abstract --	1-65

☒ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

\* Special categories of cited documents

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

Date of mailing of the international search report

26 Sept. 2001

09. 11. 2001

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 01/00417

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5943014 A (KLEIN S. GILHOUSEN), 24 August 1999 (24.08.99), abstract, see figure -- -----	1-65



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Information on patent family members

03/09/01

International application No.

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				GB	0104533 D	00/00/00
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				GB	2357223 A,B	13/06/01
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				JP	2000512101 T	12/09/00
				WO	9747148 A	11/12/97